Process-Oriented Quantitative Evaluation of IPCC CMIP5 Simulations Using A-Train Satellite Observations

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Objective

- **To use A-Train satellite observations to evaluate CMIP5 simulations of clouds and water vapor and thus contribute to IPCC AR5**
  - *Cloud feedback remains the largest uncertainty for climate projections.*
  - *Accurate simulations of current climate is a necessary condition for credible future projections.*

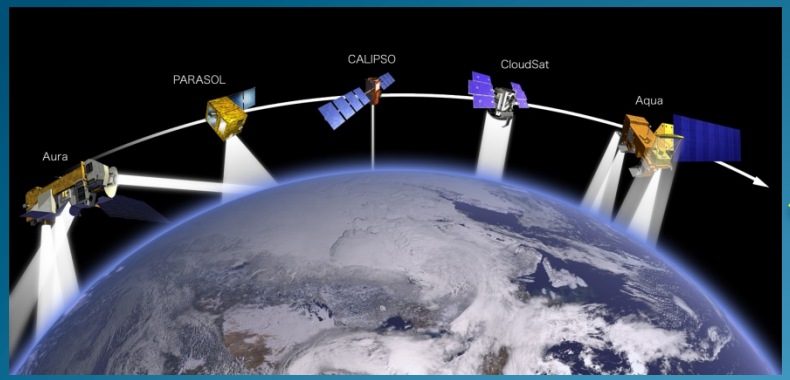


Image credit: NASA

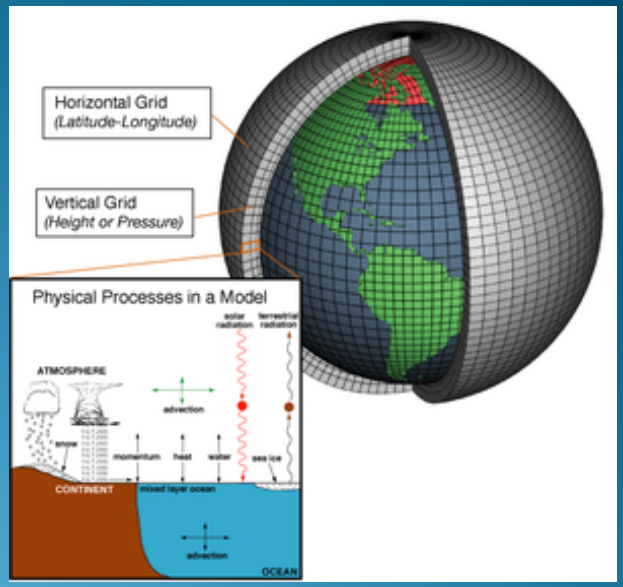


Image credit: Wikipedia/NOAA

What New Capabilities Enabled by A-Train?

1. Vertical profiles of water vapor and clouds
2. Simultaneous multiple measurements enable physics-driven process understanding
3. Knowledge of observational uncertainties enables quantitative assessment

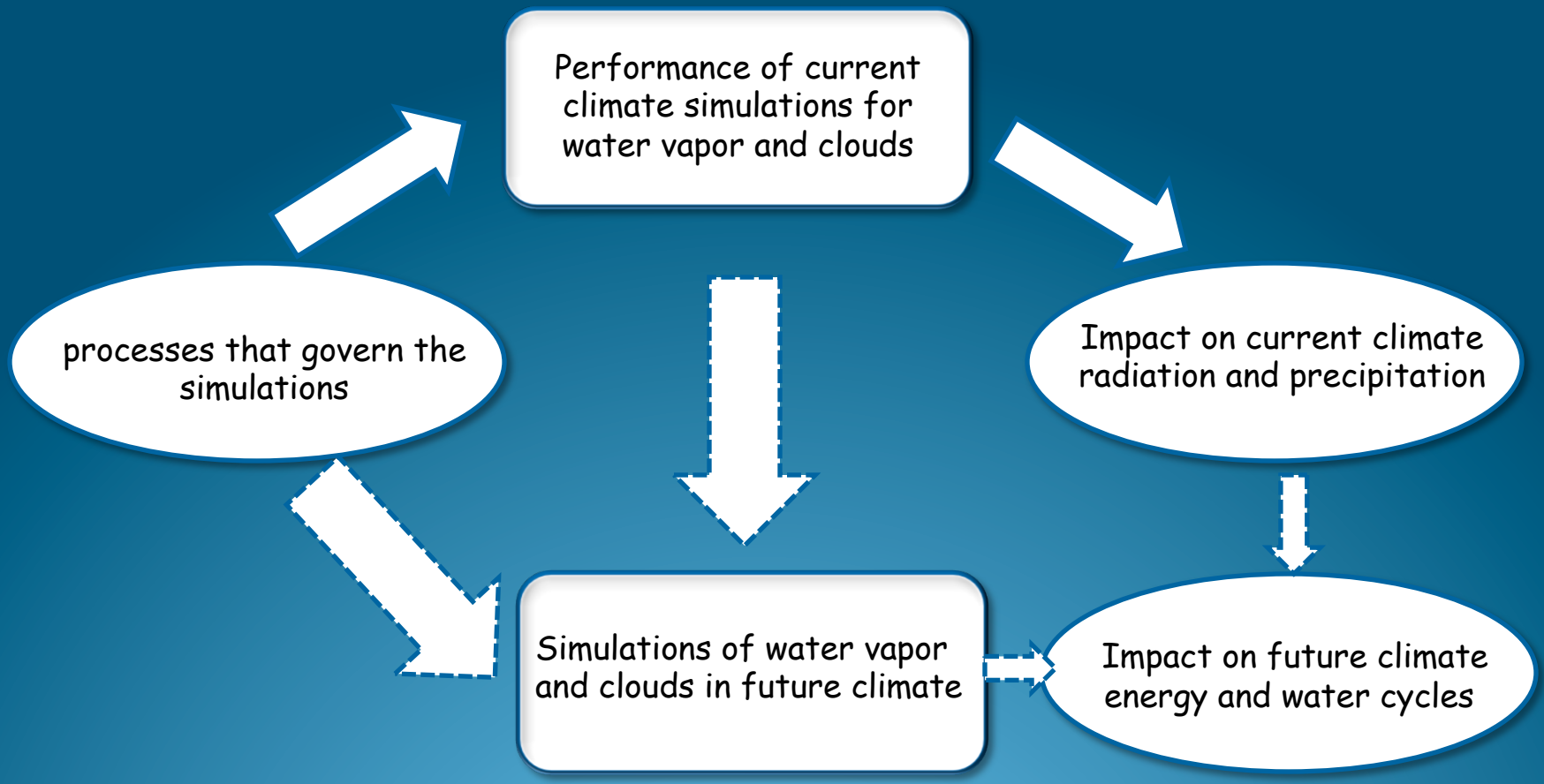
	Spatial Mean	Variance	Correlation
IWC, LWC	$G_m^{IWC,\,LWC} = \max\left[0,\ 1 - \frac{1}{n_g}\frac{\left\lvert \ln(m_{mdl}^{IWC,\,LWC}) - \ln(m_{obs}^{IWC,\,LWC}) \right\rvert}{\ln \varepsilon_{m,obs}^{IWC,\,LWC}}\right]$	$G_v^{IWC,\,LWC} = \max\left[0,\ 1 - \frac{1}{n_g}\frac{\left\lvert \ln \sigma_{mdl}^{IWC,\,LWC} - \ln \sigma_{obs}^{IWC,\,LWC} \right\rvert}{\ln \varepsilon_{v,obs}^{IWC,\,LWC}}\right]$	$G_c = \max\left[0, C_{mdl,obs}\right]$
H_2O	$G_m^{H_2O} = \max\left[0,\ 1 - \frac{1}{n_g}\frac{\left\lvert m_{mdl}^{H_2O} - m_{obs}^{H_2O} \right\rvert}{\varepsilon_{m,obs}^{H_2O}\, m_{obs}^{H_2O}}\right]$	$G_v^{H_2O} = \max\left[0,\ 1 - \frac{1}{n_g}\frac{\left\lvert \sigma_{mdl}^{H_2O} - \sigma_{obs}^{H_2O} \right\rvert}{\varepsilon_{v,obs}^{H_2O}}\right]$	

- For IWC and LWC, a logarithm of the ratio of modeled value to the observed is used due to large spread among the models.
- σ in the denominator represents the uncertainty range of the observation.
- The scaling factor n_g =3 (=4 for LWC at 900 hPa)
  - A zero *G* score means: 1) for H_2O, the model-observation difference is > 3 times the observational uncertainty; 2) for IWC and LWC, the model value is either > 2^3=8 times (16 times for 900hPa) or < 1/8 (1/16 for 900hPa) of the corresponding observation.

References: Douglass et al. [1999], Waugh and Eyring [2008], and Gettelman et al. [2010]

See Jiang et al. (2011, to be submitted)

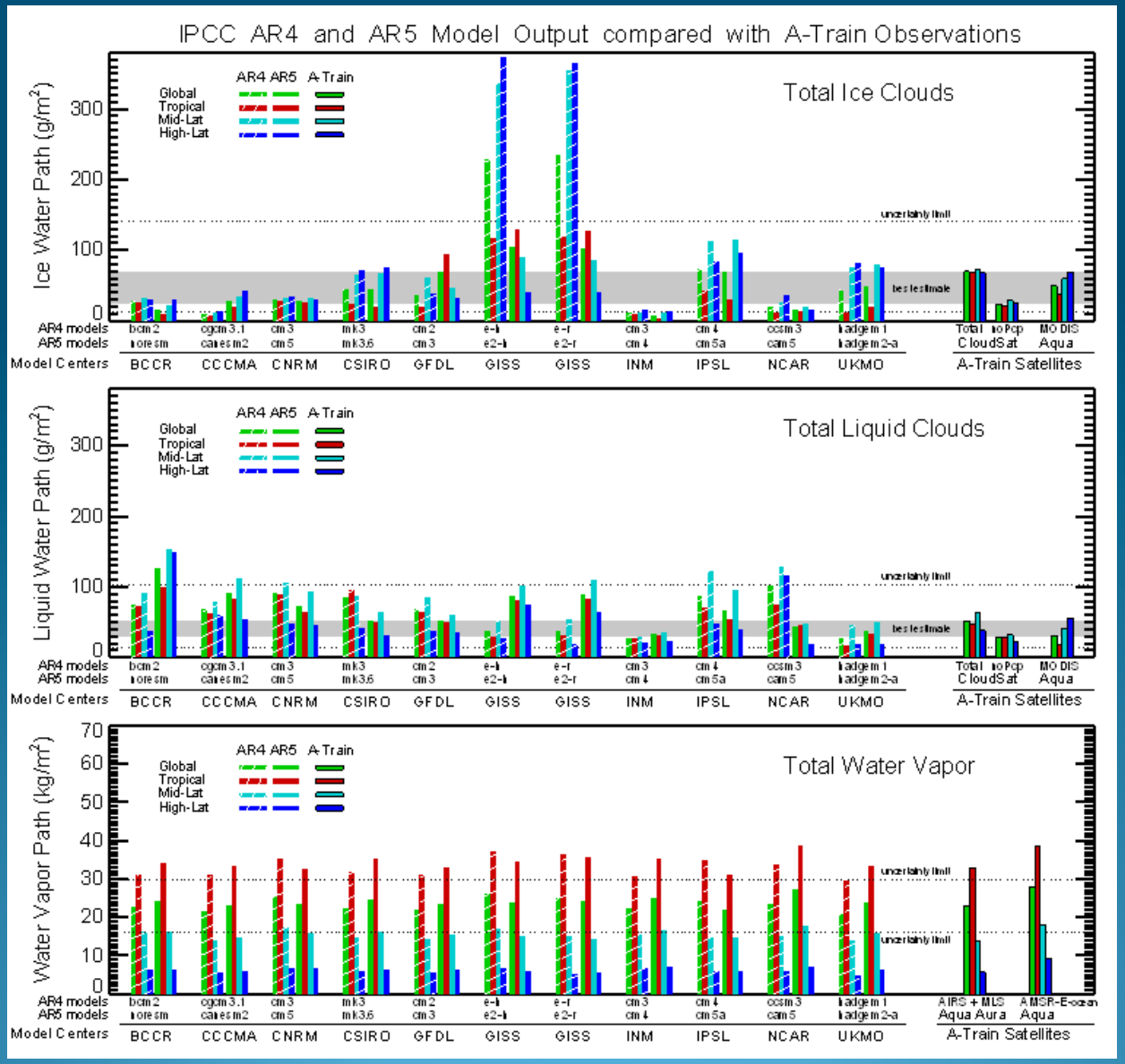
Approach


Performance of current climate simulations for water vapor and clouds
Impact on current climate radiation and precipitation
processes that govern the simulations
Simulations of water vapor and clouds in future climate
Impact on future climate energy and water cycles

Step 1

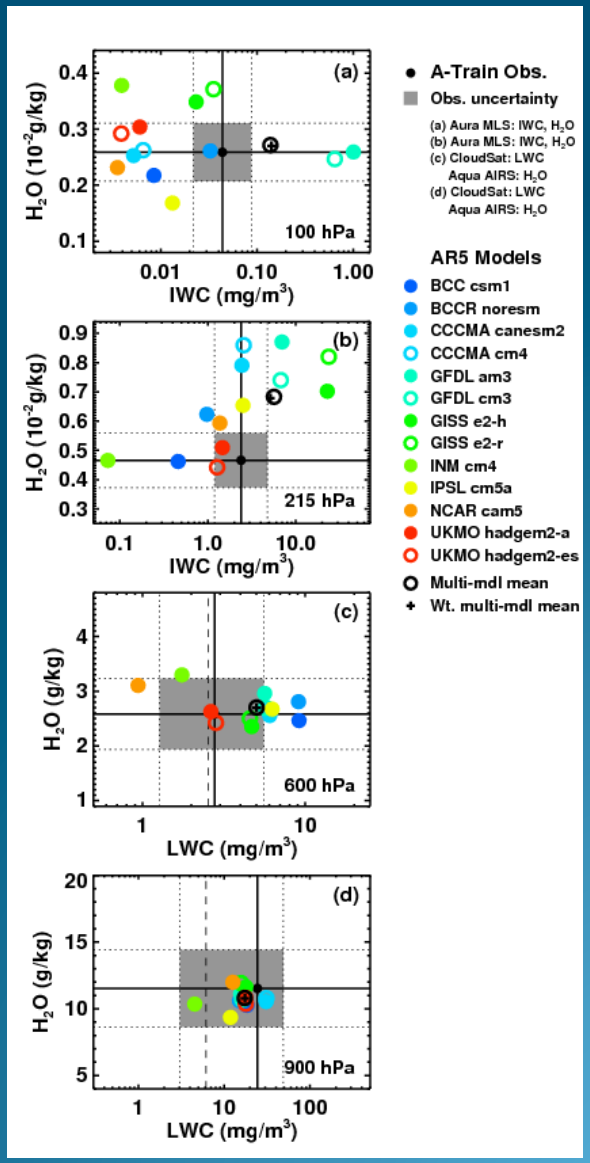
Performance of current climate simulations for water vapor and clouds

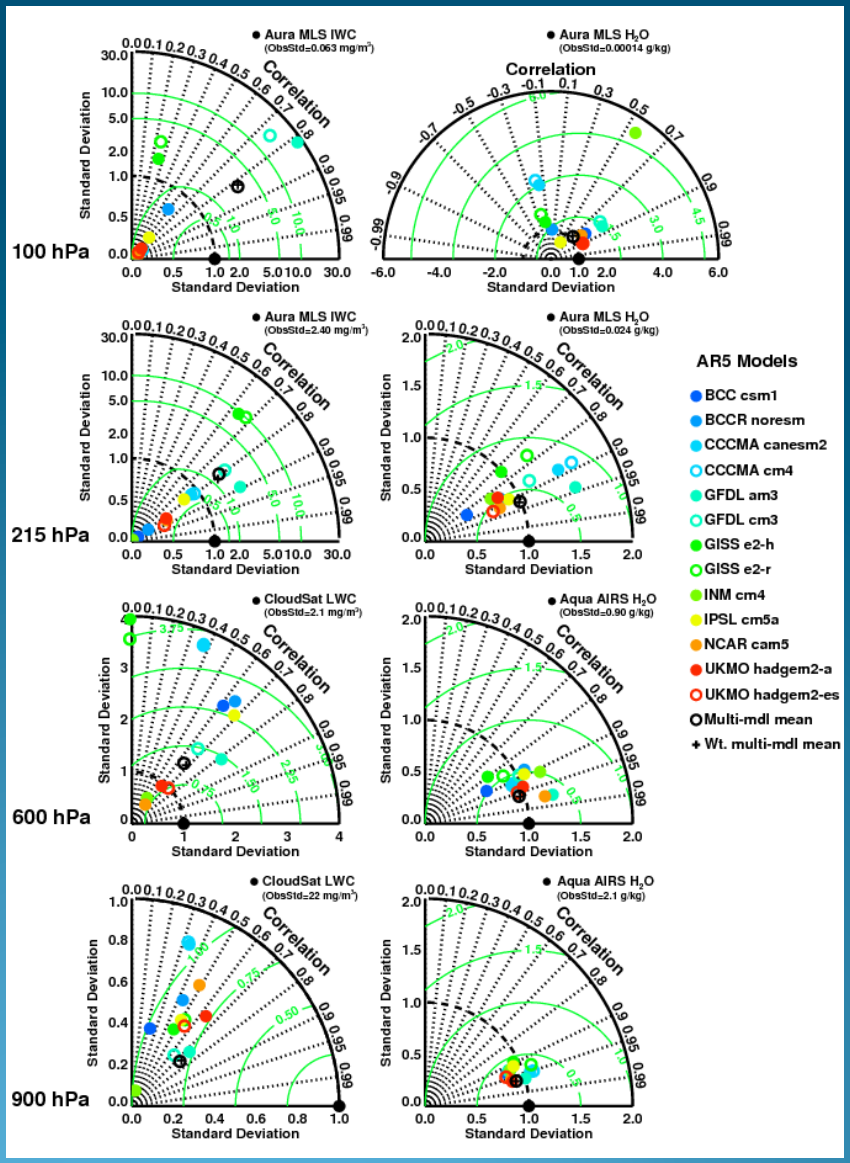
Evaluation of Multi-year Climatology



Jiang et al. (2011, to be submitted)

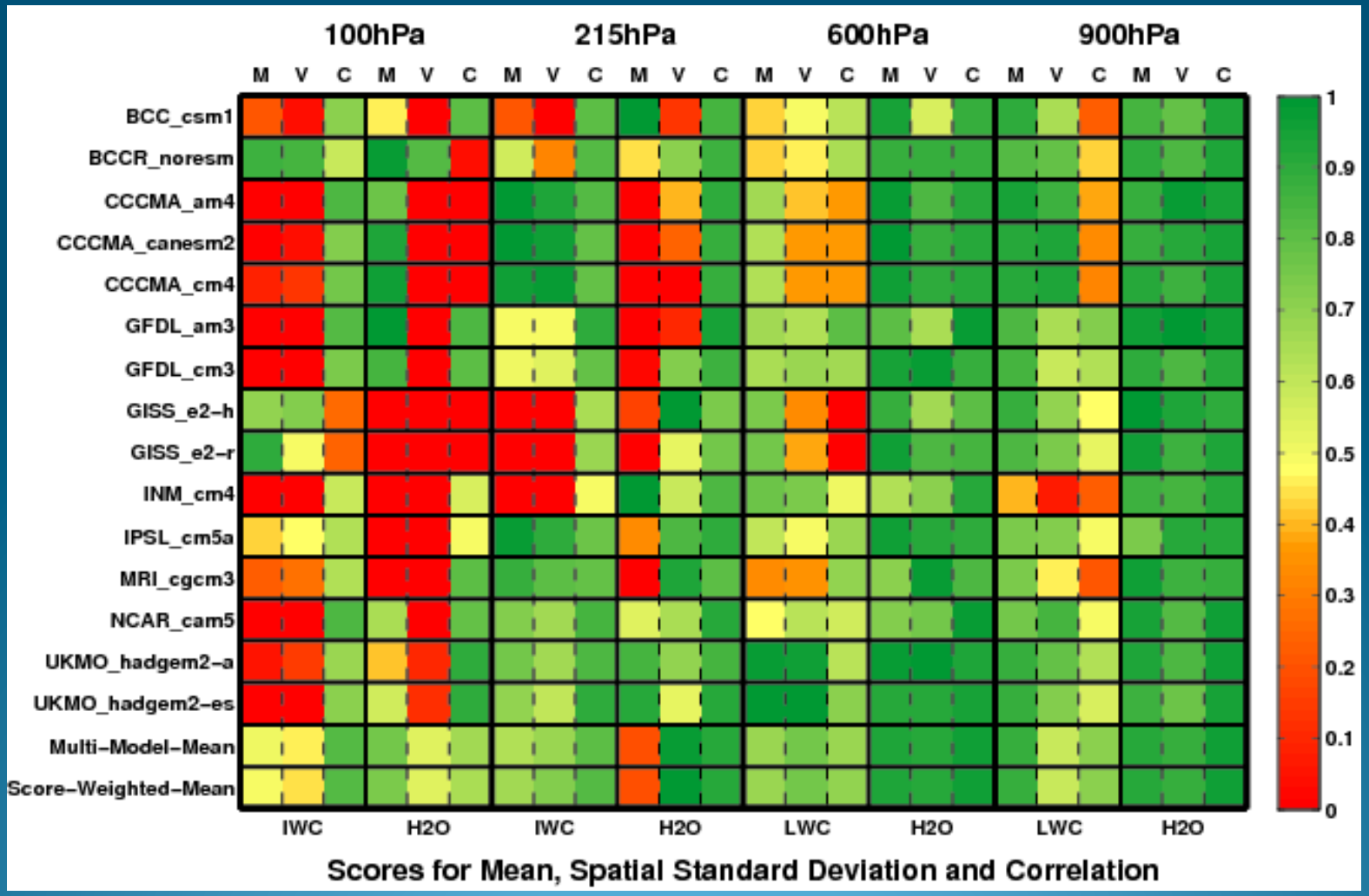
Comparing Spatial Mean, Variance and Correlation





Jiang et al. (2011, to be submitted)

Model Performance



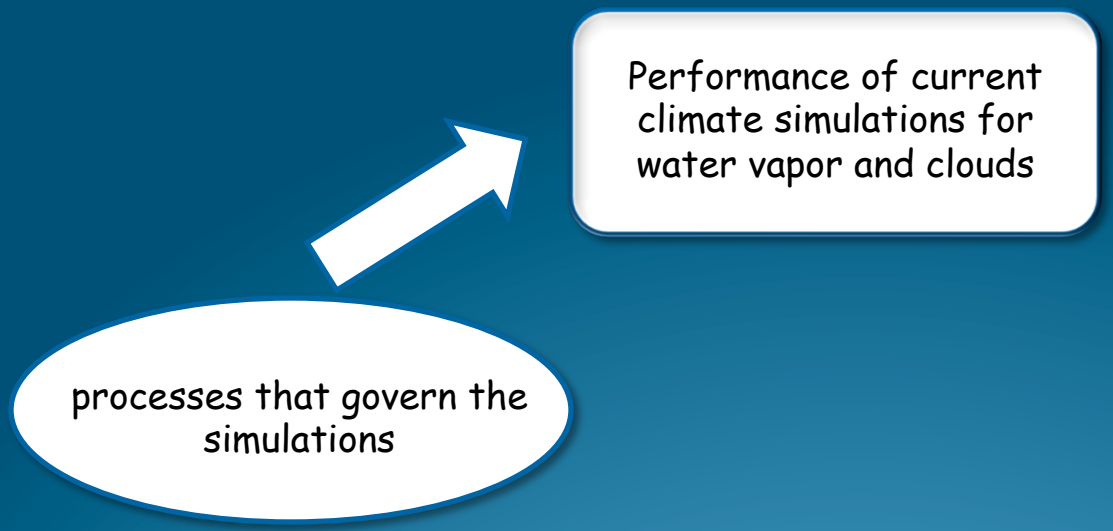
Jiang et al. (2011, to be submitted)

Overall Score and Rank

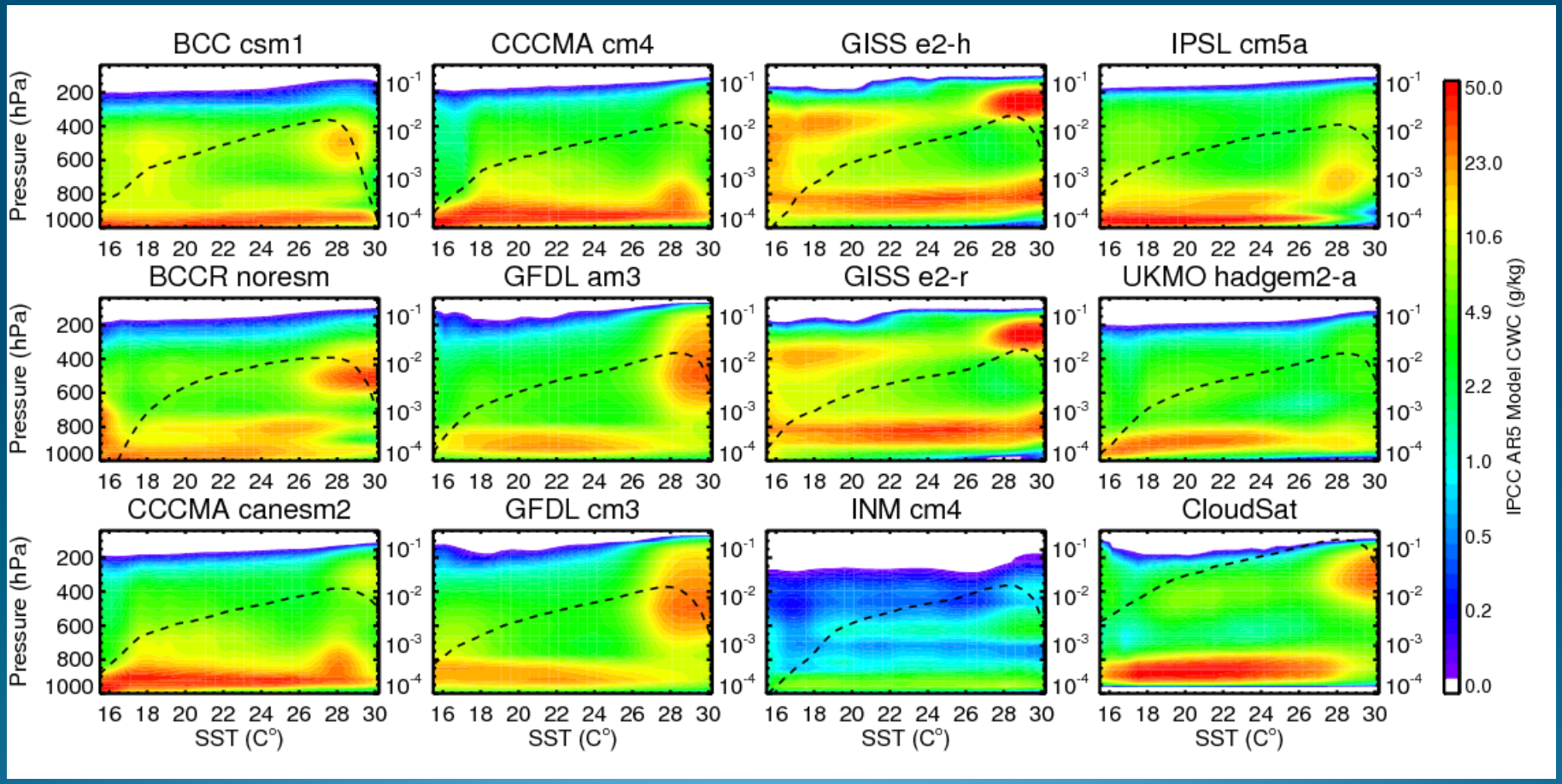
AR5 Model	Overall Score	Rank
BCC csm1	0.56	8
BCCR noresm	0.70	3
CCCMA canesm2	0.61	7
CCCMA cm4	0.61	7
GFDL am3	0.64	6
GFDL cm3	0.64	6
GISS e2-h	0.52	9
GISS e2-r	0.51	10
INM cm4	0.49	11
IPSL cm5a	0.66	4
NCAR cam5	0.65	5
UKMO hadgem2-a	0.73	1
UKMO hadgem2-es	0.71	2
Multi-model-mean	0.74	
Weighted multi-model-mean	0.75	

Jiang al. (2011, to be submitted)

Step 2


Performance of current climate simulations for water vapor and clouds
processes that govern the simulations

Conditional Sampling



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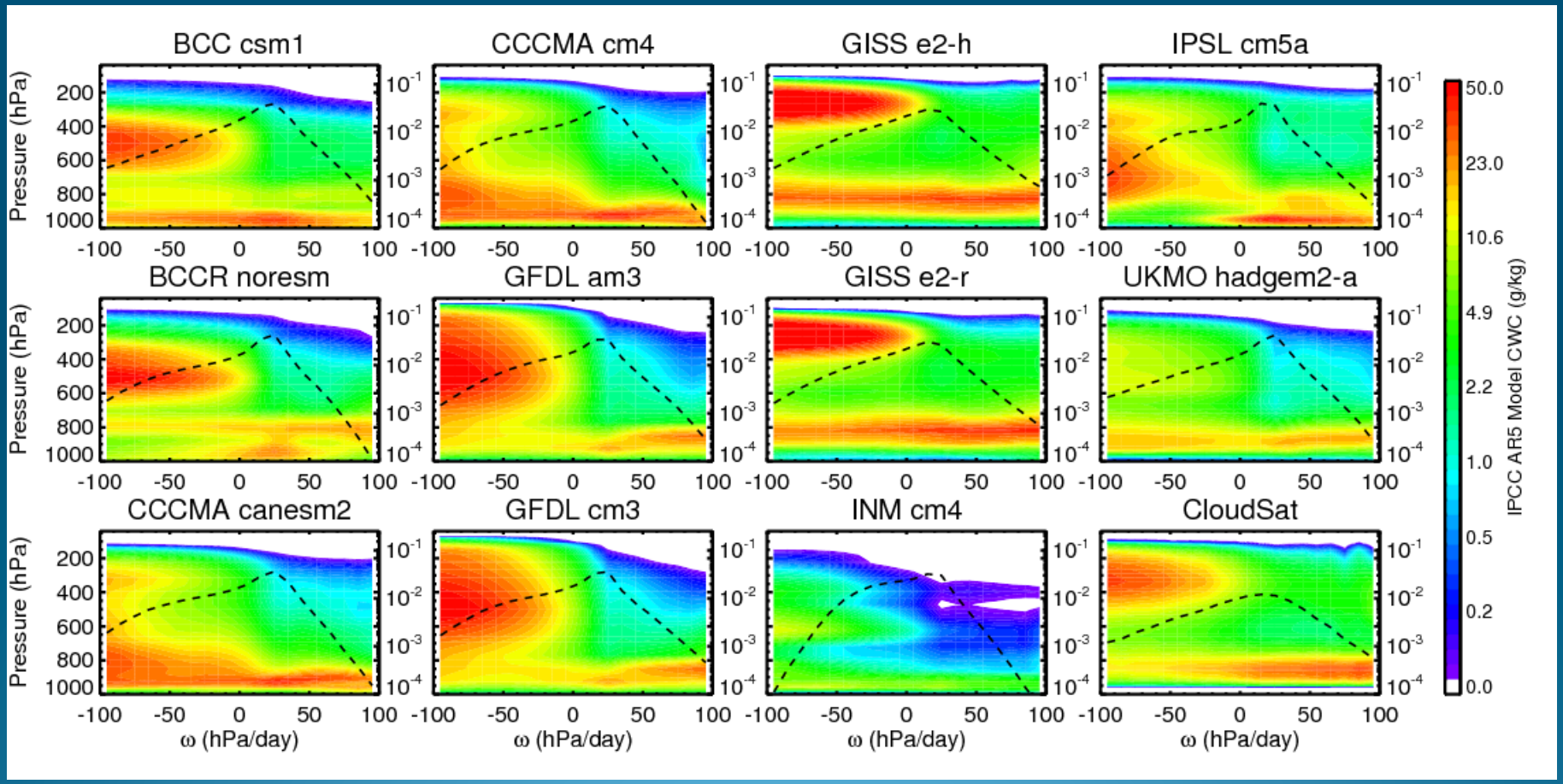
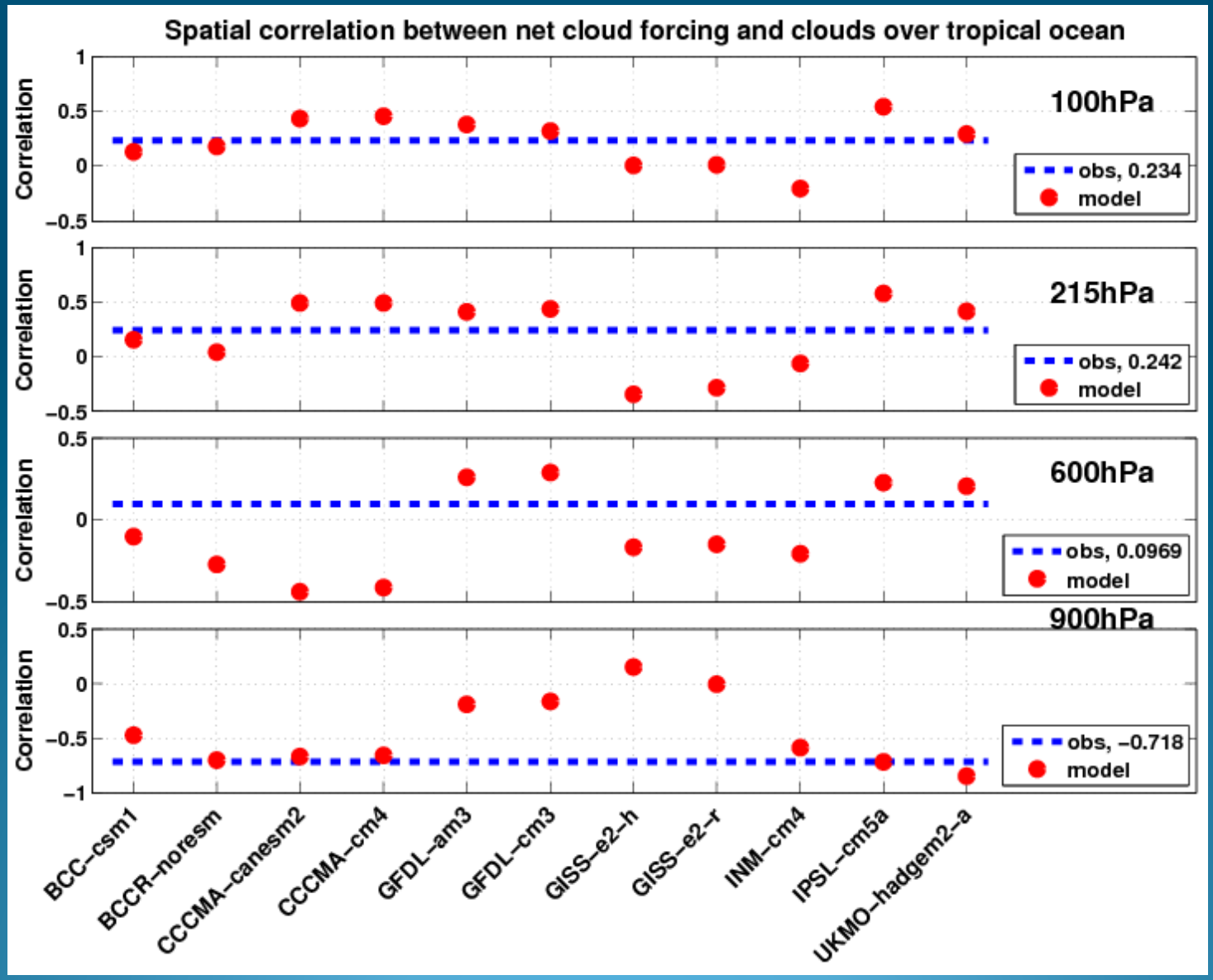


Step 3

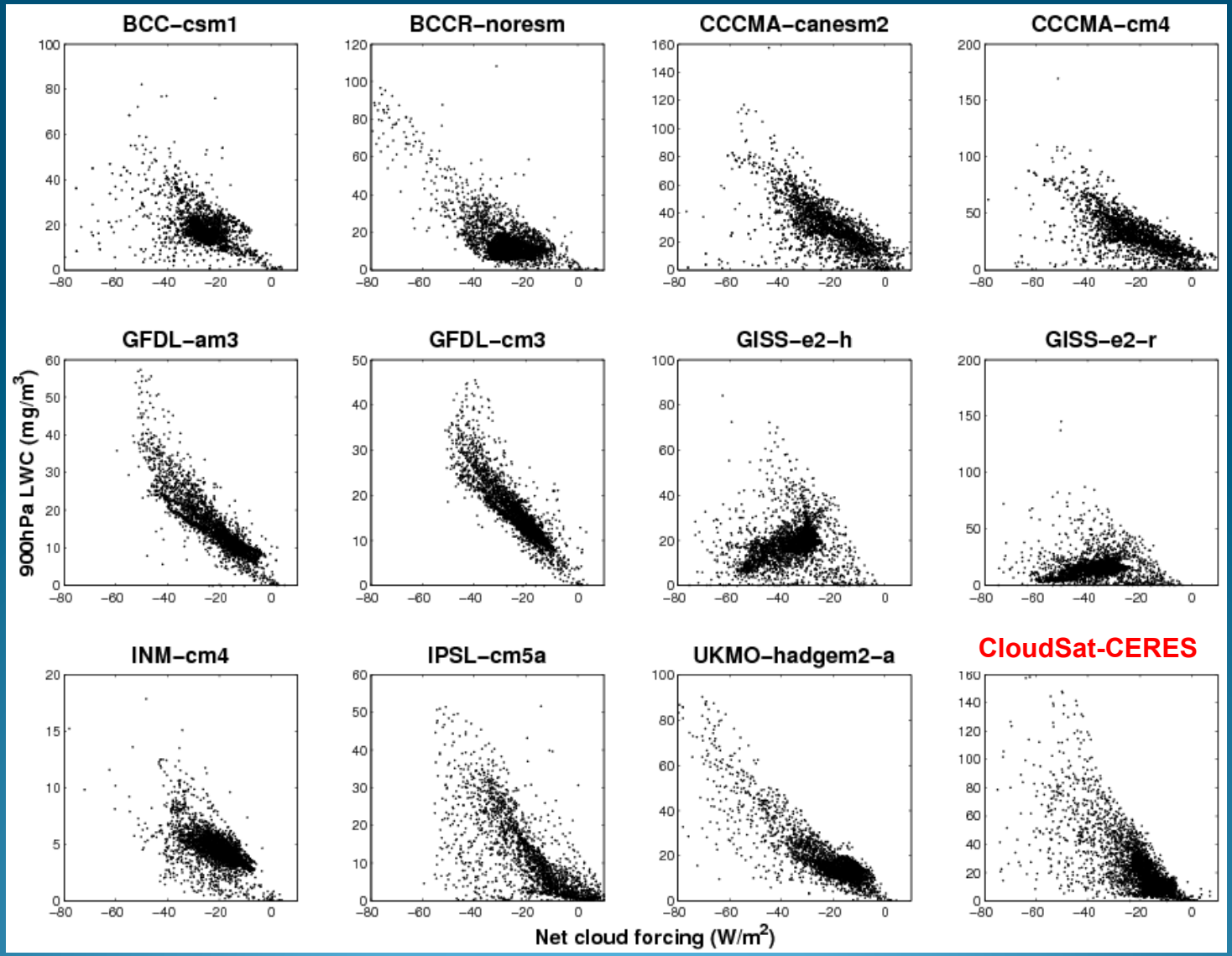
Performance of current climate simulations for water vapor and clouds

Impact on current climate radiation and precipitation

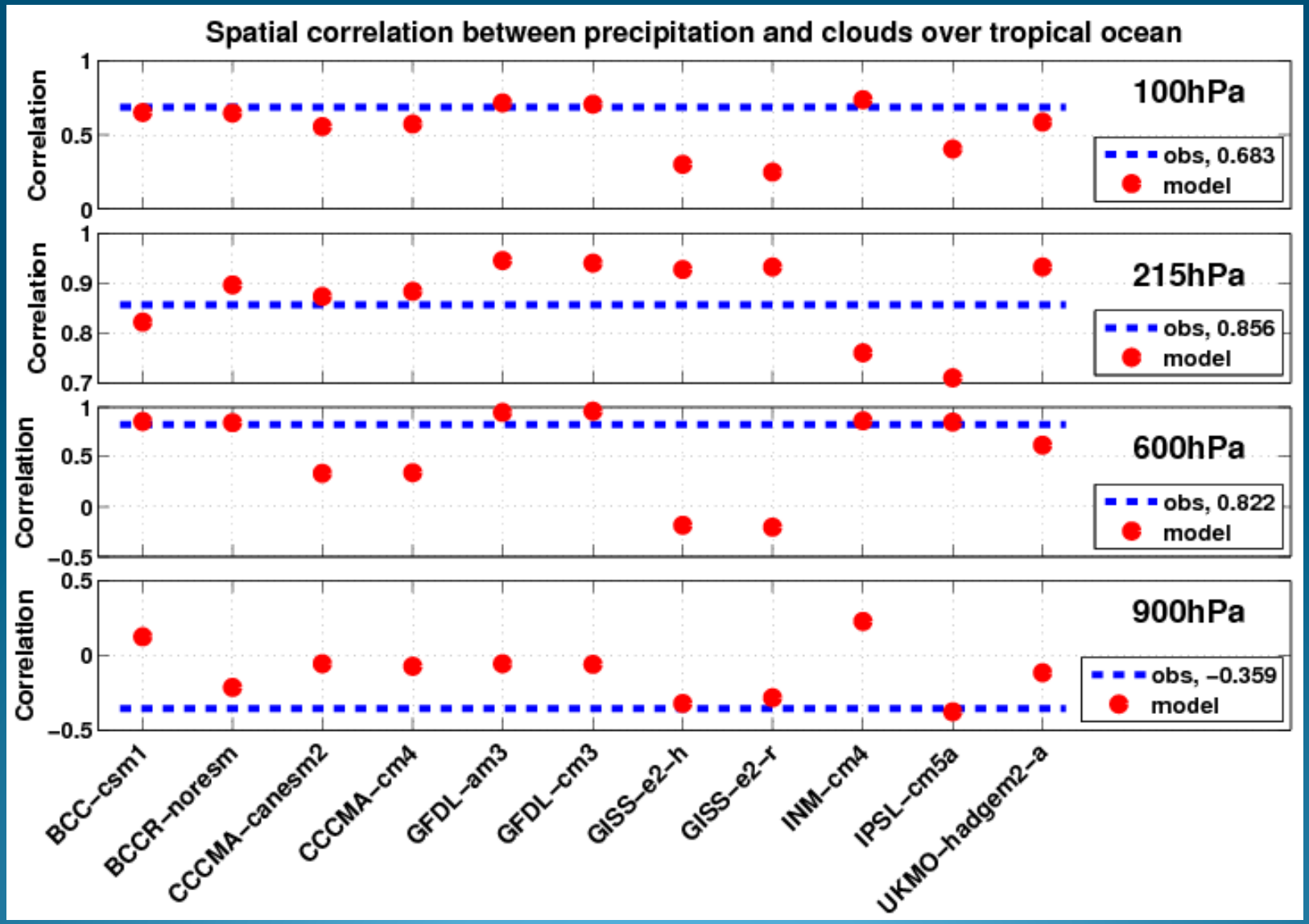
Model Spread in Cloud Forcing Sensitivity



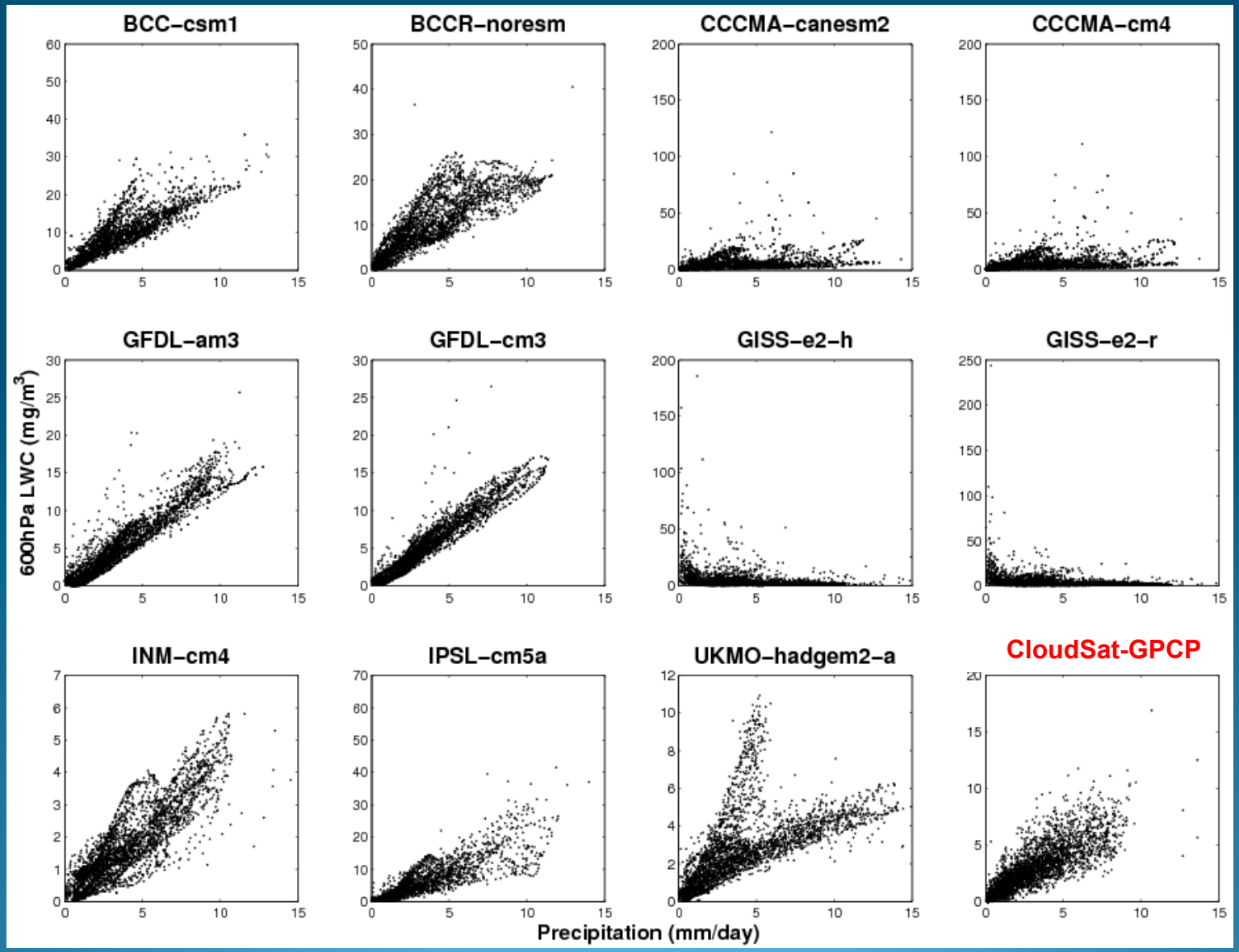
Model Spread in Cloud Forcing Sensitivity



Model Spread in Precipitation Sensitivity



Correlation with Precipitation



600 hPa

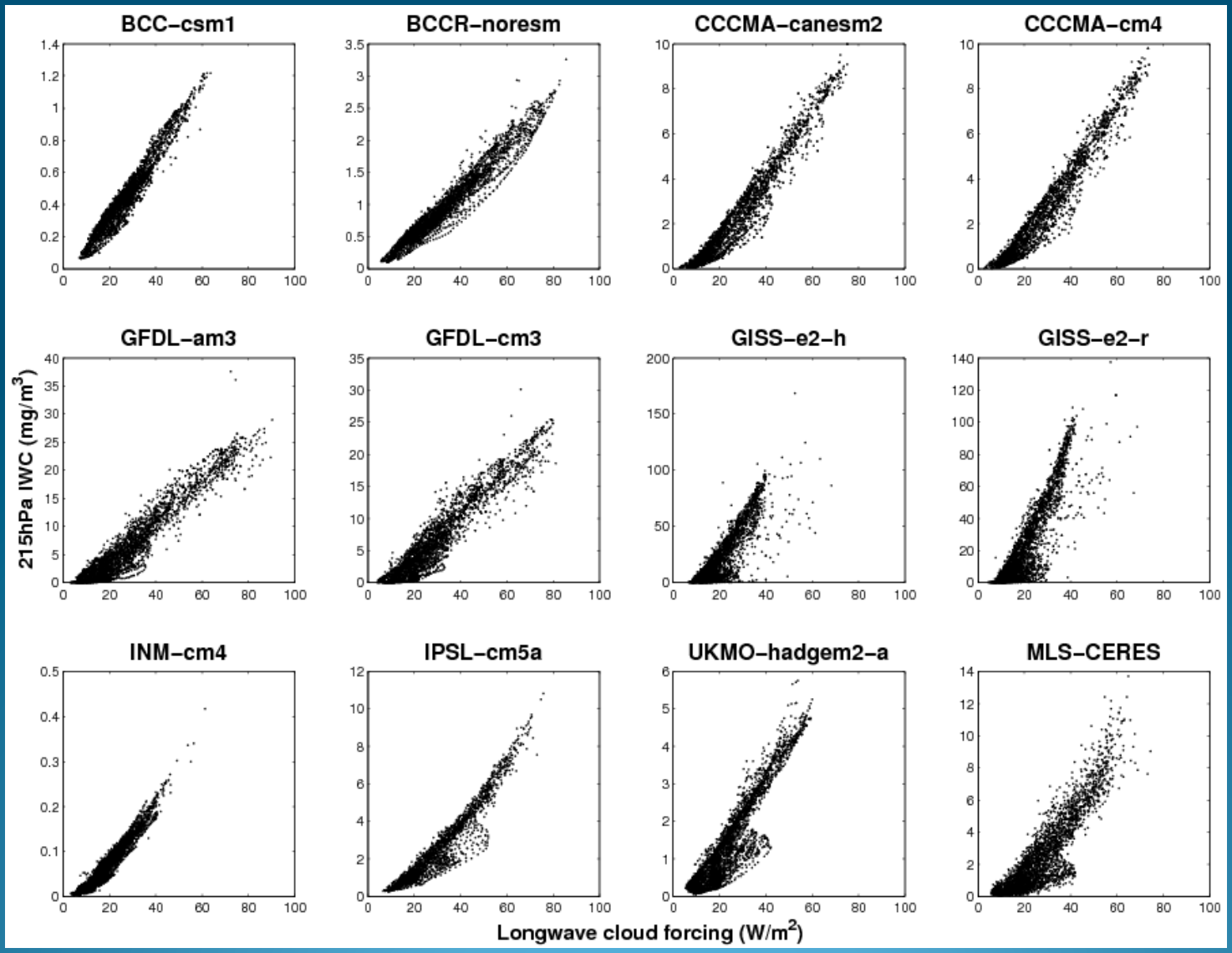
Summary

- Significant improvements are found from CMIP3 to CMIP5 in simulated IWP and LWP.
- Water vapor is generally better simulated than clouds.
- Model spreads in the upper troposphere are much larger than those in the lower and middle troposphere.
- The simulated relationships of clouds with large-scale dynamic and thermodynamic regimes are drastically different -> large errors in model physics
- Boundary layer clouds constitute the largest spread for the net cloud forcing sensitivity
- Mid-tropospheric clouds constitute the largest spread for the precipitation sensitivity

More work is needed ……

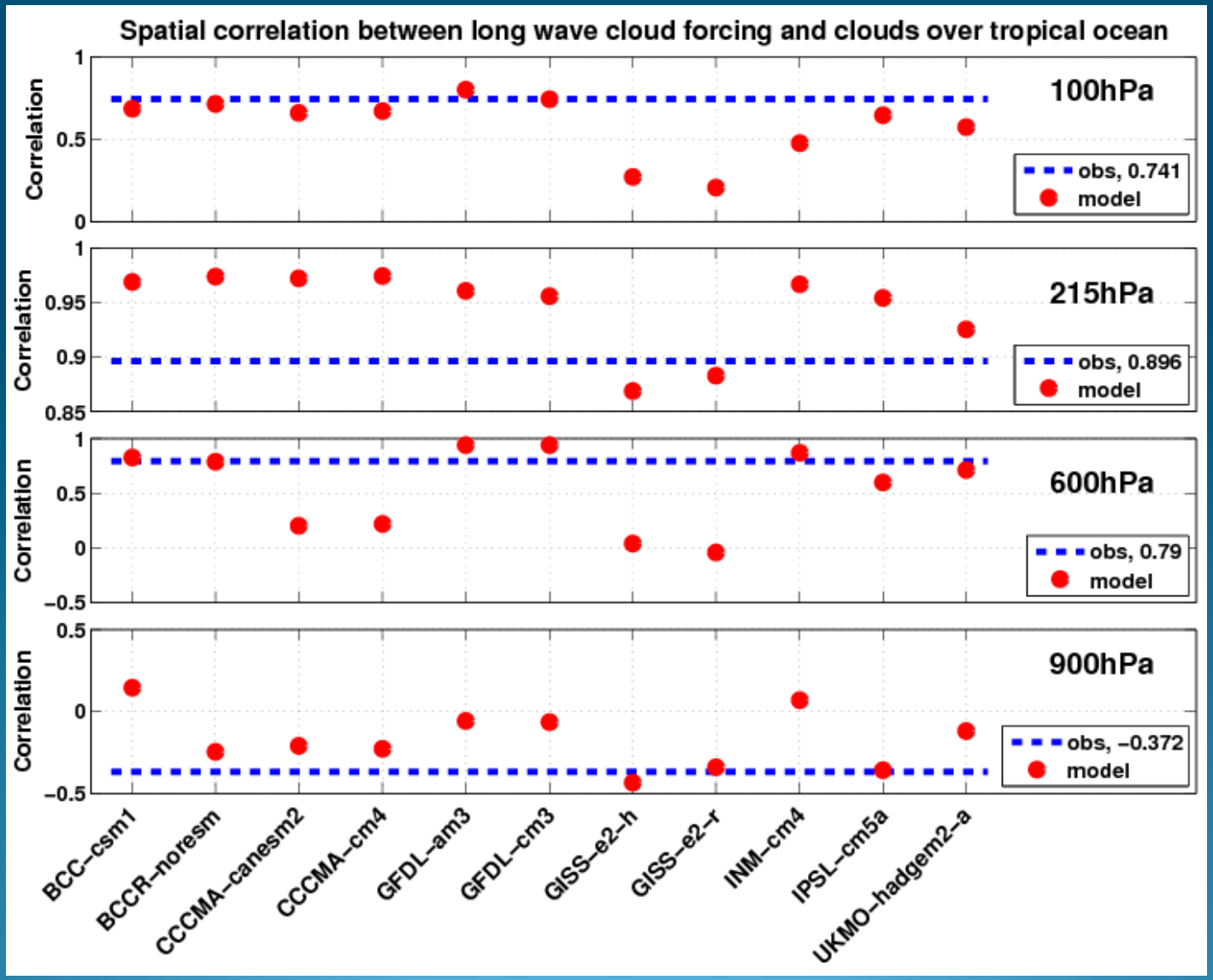
Back-up Slides

Relevance to TOA Cloud Forcing

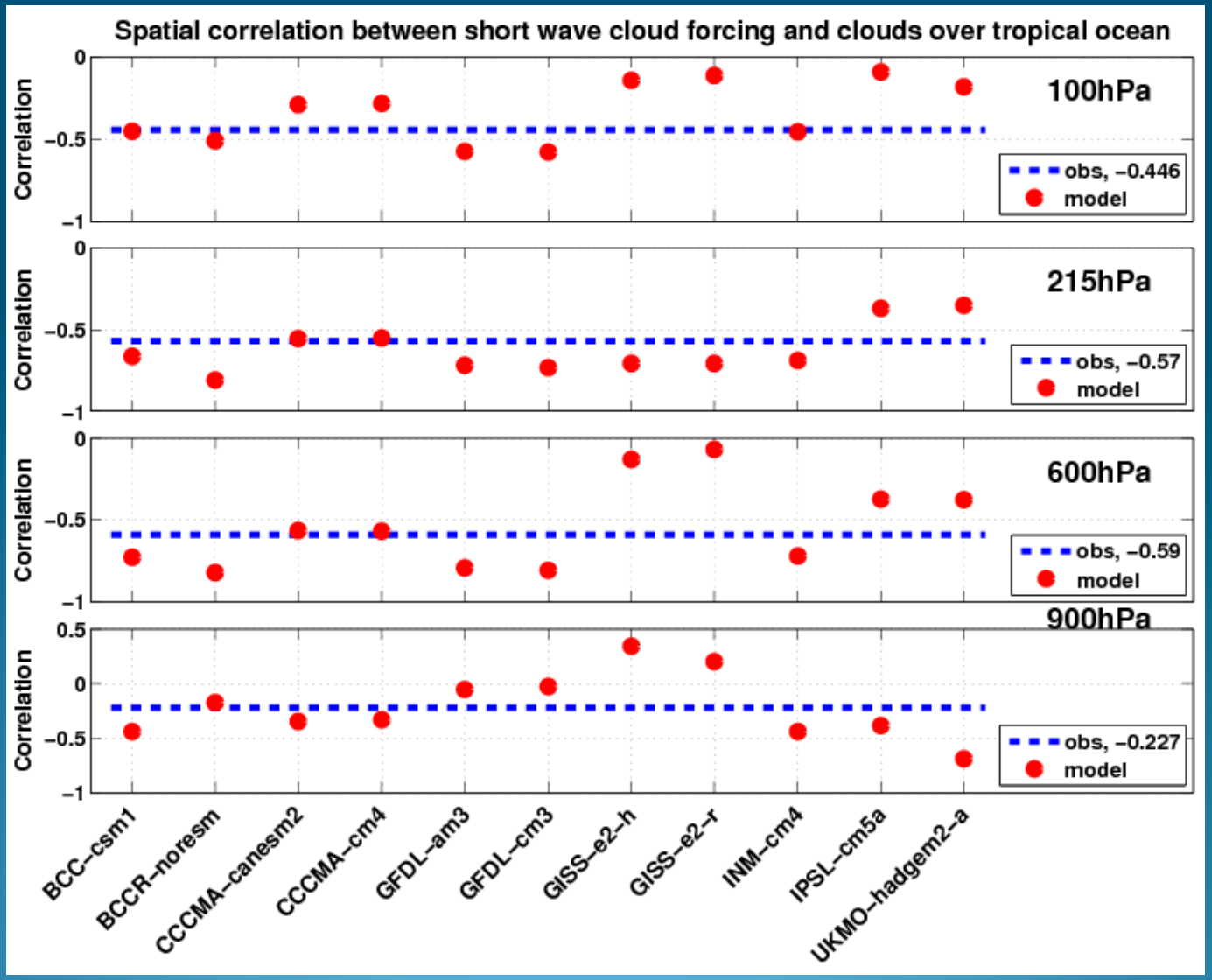


200 hPa

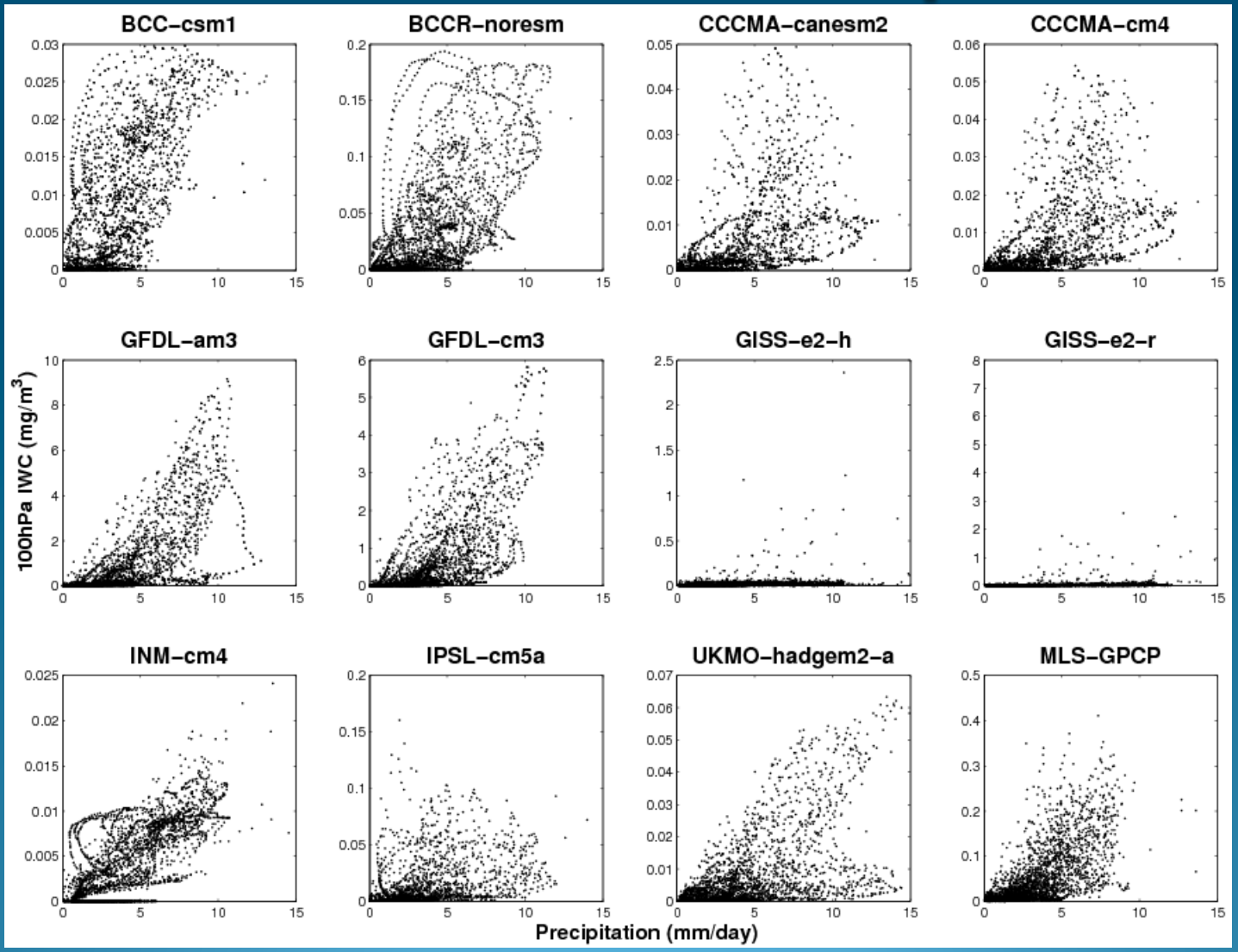
Model Spread in Cloud Forcing Sensitivity



Model Spread in Cloud Forcing Sensitivity

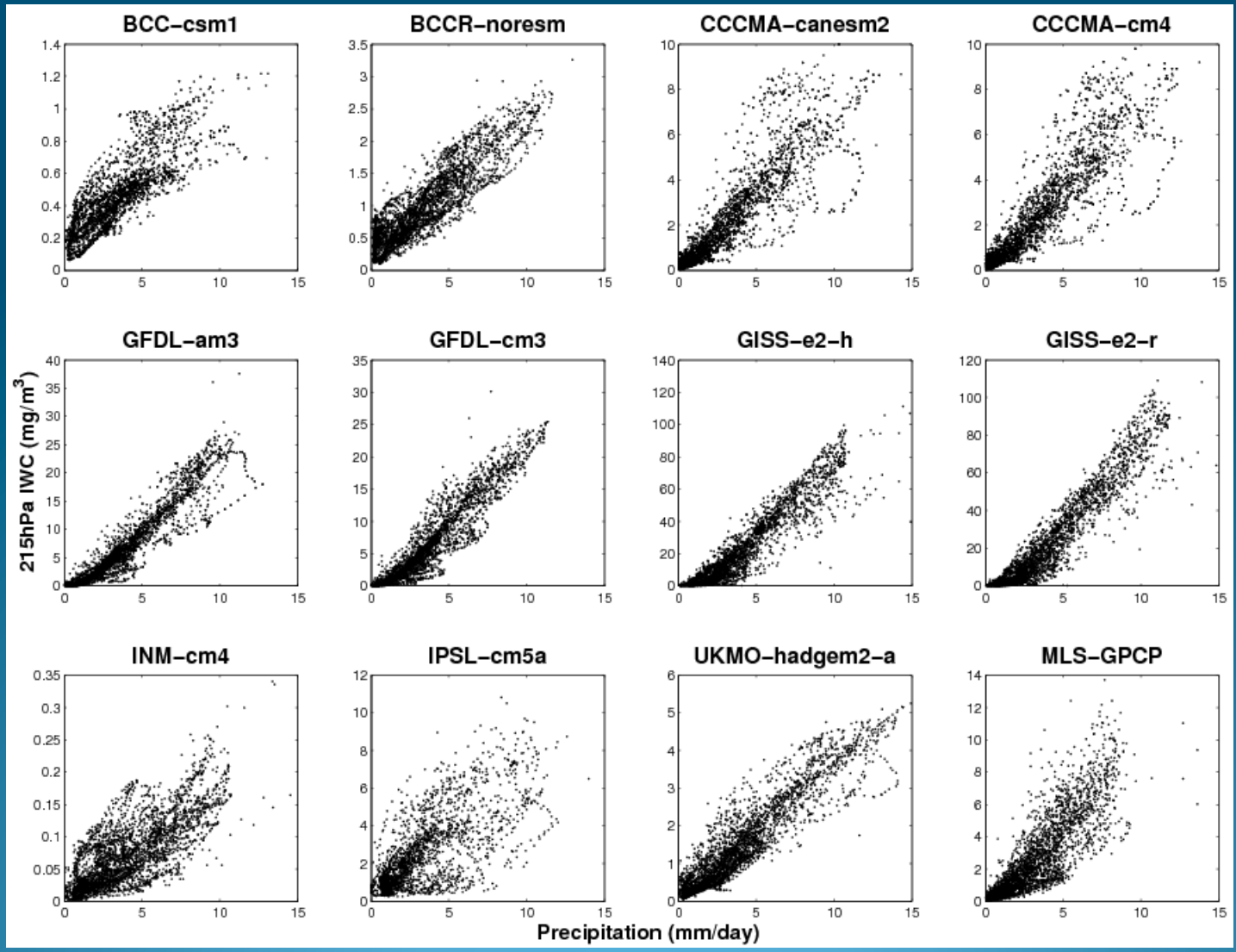


Correlation with Precipitation



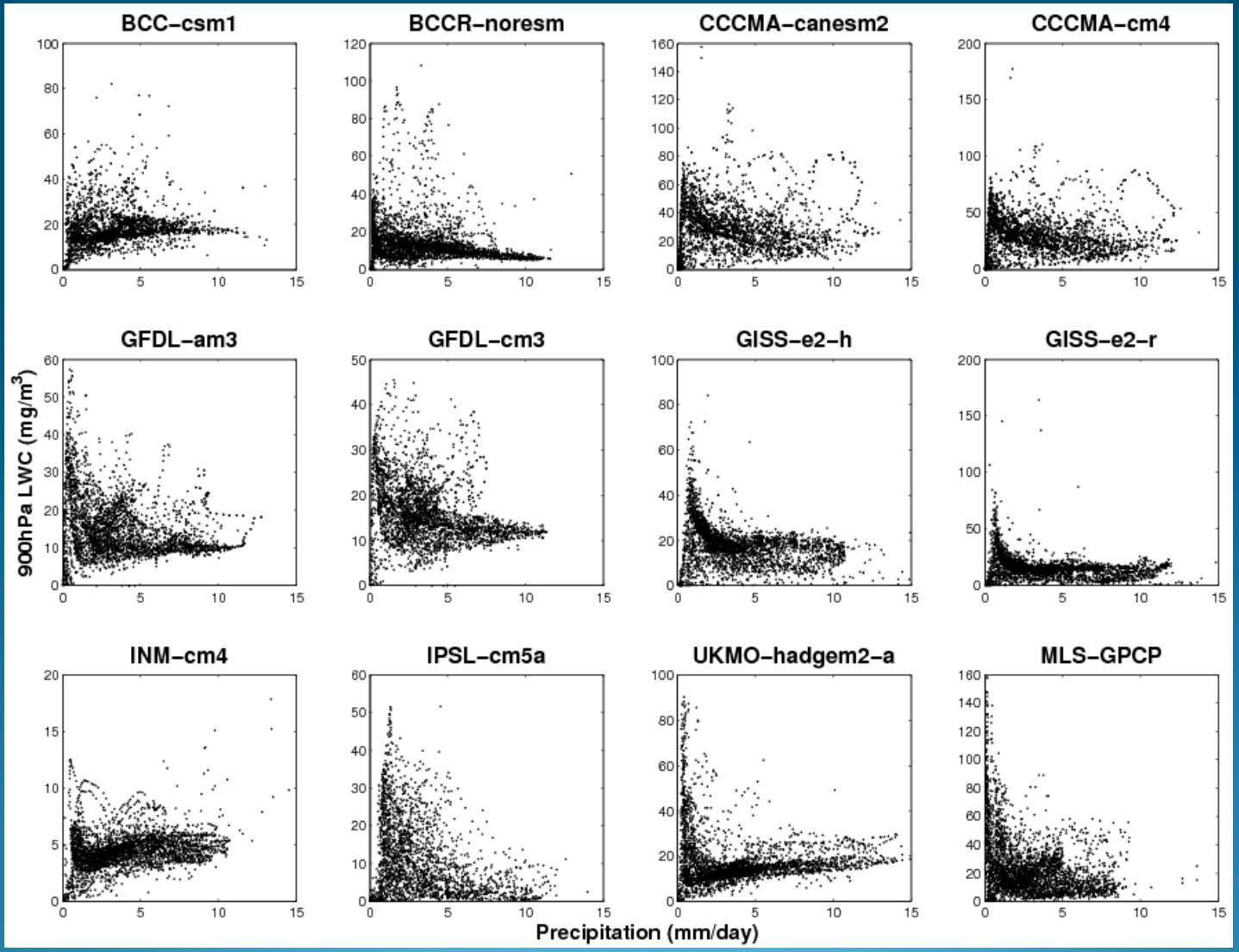
100 hPa

Correlation with Precipitation



215 hPa

Correlation with Precipitation



900 hPa